DRAFT

CALIFORNIA ENERGY COMMISSION STAFF BIOCIDE MONITORING PROGRAM GUIDELINES For Wet and Hybrid Cooling Towers at Power Plants May 15, 2003 Version 1.0

A. Background

Recent studies have shown that a low, yet non-zero possibility exists for bacterial growth to occur in power plant cooling towers, including Legionella (1, 2, 6, 8, 10, 15, 20). Legionella is a type of bacteria that grows in water (optimal temperature of 37° C) and causes Legionellosis, otherwise known as Legionnaires' Disease. Untreated or inadequately treated cooling systems in the United States have been correlated with outbreaks of Legionellosis. These outbreaks are usually associated with building heating, ventilating, and air conditioning (HVAC) systems, but it is possible for growth to occur in industrial cooling towers. In fact, Legionella bacteria have been found in drift droplets. The U.S. Environmental Protection Agency (EPA) published an extensive review of Legionella in a human health criteria document (8). The EPA noted that Legionella survival is enhanced by symbiotic relationships with other microorganisms, particularly in biofilms, and that aerosol-generating systems, such as cooling towers, can aid in the transmission of Legionella from water to air (8, 9).

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE 1, 10, 15) states that good preventative maintenance is very important in the efficient operation of cooling towers and other evaporative equipment. Preventive maintenance includes having effective drift eliminators, periodically cleaning the system if appropriate, maintaining mechanical components in working order, and maintaining an effective water treatment program with appropriate biocide concentrations. The following management strategies are directed at minimizing colonization/amplification within the cooling tower system:

- Avoid piping that is capped and has no flow (dead legs).
- Control input water temperature to avoid temperature ranges where Legionella grow. Keep cold water below 25° C (77° F) and hot water above 55° C (131° F).
- Apply biocides in accordance with label dosages to control growth of other bacteria, algae, and protozoa that may contribute to nutritional needs of Legionella. Rotating biocides and using different control methods is recommended. These include thermal shock, oxidizing biocides, chlorine-based oxidants and ozone treatment.
- Conduct routine periodic "back-flushes" to remove bio-film buildup on the inside walls of the pipes.

In 2000, the Cooling Tower Institute (CTI) issued a report and guidelines for the best practices for control of Legionella (6). To minimize the risk from Legionella, the CTI noted that consensus recommendations included minimization of water stagnation, minimization of process leads into the cooling system that provide nutrients for bacteria, maintenance of overall system cleanliness (13, 14), the application of scale and corrosion inhibitors as appropriate, the use high-efficiency mist eliminators on cooling towers, and the overall general control of microbiological populations.

This need for microbial control and reduction of the potential for Legionella growth was also recognized by the California Department of Health Services, which adopted a regulation addressing this issue (5). The California Code of Regulations, Title 22, Section 60306 states, in part, that whenever a cooling system, using recycled water in conjunction with an air conditioning facility, utilizes a cooling tower or otherwise creates a mist that could come into contact with employees or members of the public, the cooling system shall comply with the following:

1. A drift eliminator shall be used whenever the cooling system is in operation.
2. A chlorine, or other, biocide shall be used to treat the cooling system recirculating water to minimize the growth of Legionella and other micro-organisms.

Given this background, it is clear that a need exits for the CEC to give guidance to power plant owners on methods to control, to the maximum extent feasible, microbial growth within a cooling tower that uses open recirculating water systems (8, 11, 12). The goal is to reduce the risk of Legionella bacteria growing or presenting a health hazard to workers or the off-site public. The CEC is therefore providing these guidelines as an example of a biocide application and monitoring program showing how to control microorganisms. The objective is to minimize biofilm growth, biofouling, and Legionella.

B. Protocol

1. Selection of Biocide

It has been demonstrated that the use of halogen-based oxidants as the routine biocide in the cooling system is the most effective treatment for control of microbial growth. Therefore, a halogen-based biocide shall be used. Examples include sodium hypochlorite, liquid stabilized bromine (16, 18), or a solid halogen donor (e.g. hydantoin). The preferred biocide for new applications is sodium hypochlorite. Some technicians state that hydantoin or liquid stabilized bromine may be used on small towers (20). Non-oxidizers such as isothiazoline, glutaraldehyde, and Dibromonitrilopropionamide (DBNPA), may be used on a contingency basis, but this is discouraged. If a biofilm forms, a biodispersant at concentration of 5 - 25 ppm should be added with the halogen until microbial testing indicates the system is back in control.

2. Biocide Control Ranges

Continuous feed of halogen is one of the most significant factors in controlling Legionella (2, 20). The recommended chlorine residual is intended to control biofilm growth.

- Hypochlorite shall be fed to continuously maintain 0.3 - 0.7 ppm free chlorine residual by the Diethly-p-phenylenediamine (DPD or the dimethyl-substituted form DDPD) method.

- Stabilized bromine products (e.g. hydantoin) shall be fed to continuously maintain 0.5 -1.0 ppm total halogen (as ppm $C1_2$) residual.

- Typical non-oxidizing biocide dosages include:
  - Isothiazoline (1.5%) - 75 ppm shock
  - Glutaraldehyde (45 %) - 100 ppm
  - DBNPA (20%) - 40 ppm

If other non-oxidizers are used, follow manufacture's instructions on dose. If ammonia is present in significant concentrations or the pH is >8.5, follow the recommendations of Betz Dearborn Technical Bulletin 73 (2).

3. Microbial Testing

Microbial testing has been shown to be an effective measurement of the efficiency of control methods (2, 3, 4, 7, 17, 22) and is recommended by Australia, Betz-Dearborn, and Shell Chemical Company (3, 18, 19)

- The cooling water shall be tested for total microbiological (MB) counts (aerobic planktonic bacteria, 48 hr incubation) once per week. Acceptable results indicating good microbial control would be less than or equal to 10^4 CFU/ml (Colony Forming Units per milliliter).

- The cooling water shall be tested for total anaerobic sulfate-reducing bacteria (SRB's) once per month. Action shall be taken when there is a "positive" (black agar) test result.

4. Upsets

When the system is found to be out of microbial control or if upsets occur, the following procedures shall be used to return the system to normal control.

- Shock treatment with a halogen-based biocide shall be done when any of the following conditions apply:
  - The free or total halogen lower limit has not been met for 48 hours or more;
  - There are two total MB count test results greater than10^4 CFU/ml in a row; or
  - The anaerobic test result comes back "positive".

- Shock treatment shall consist of increasing the free residual chlorine to1- 2 ppm chlorine for 4 hours. If microbial testing was the reason for the upset condition, testing should be redone within 24 hours of the shock treatment. If free residual chlorine of 1-2 ppm can not be achieved, or the new microbial test result is still > 10^4 CFU/ml, or the anaerobic test result is still "positive", the system shall be shock treated with a non-oxidizing biocide and microbial testing should be conducted again after two days.

Shock treatment should be continued with the non-oxidizer every two days until the free chlorine residual is maintained at 1-2 ppm. If microbial monitoring tests are still not under control, the dosage and/or frequency of the non-oxidizer should be increased. The free residual halogen should also be increased to 0.8 — 1.2 ppm. Microbial testing should be conducted again after two days.

- If this is not successful, or if the system continues to require a high level of biocide for control, further corrective measure must be implemented. These measures include visual inspection for leaks and subsequent shut down and repair. The area around the tower should be restricted and personal protective equipment (PPE) required for entrance into the restricted area until microbial control is re-established. Process leaks are often a cause of biofouling within a cooling system. Process leaks become a source of nutrients for bacteria, result in an accumulation of sludge, and foul heat exchange equipment. There should be a detailed procedure for finding a leak and it should be implemented if a leak is suspected. Decisions about when to repair the leak are complex. They involve assessing safety and environmental risks (e.g. inability to maintain microbial control increases risk for Legionella growth) as well as corrosion and fouling risks. Following correction and recovery from the problem, disinfection will be required. Two weeks after this, the cooling water shall be sampled for Legionella (see section 6 below).

5. Cooling Tower Shutdown, Startup, and Maintenance

- If a tower is to be entered, it shall be disinfected first by shocking the system with a non-oxidizing biocide two days before entrance and shocking with a halogen to 2-2.5 ppm residual one day before entrance.

- At startup, the tower shall again be disinfected, first with shock treatment with hypochlorite, followed by a non-oxidizing biocide when halogen residuals return to normal.

- The tower basin should be cleaned (sludge removed) whenever the whole tower is down.

- Drift eliminators shall be annually inspected for cleanliness and gaps/bypassing. Inlet distributors shall be annually inspected for plugging.

6. Legionella Monitoring

- When sampling for Legionella, obtain the water from the tower basin away from where makeup enters the basin. (See OSHA guidelines (21) where additional sampling or investigation is needed.)

- If testing shows Legionella at <10 CFU/ml, the system is under control and no further action is required.

- If testing shows Legionella at 10 - 100 CFU/ml, the cooling tower must be disinfected per section 5 and re-sampled for Legionella after 2 weeks.

- If testing shows Legionella at >100 CFU/ml, access to the area around the tower shall be controlled to those wearing appropriate PPE. An emergency disinfection procedure shall be implemented and a process risk assessment shall be prepared to identify the causal or contributing factors to the Legionella proliferation. Methods shall be implemented to minimize these factors. The tower shall be re-tested for Legionella after two weeks.

7. Record Keeping

Documents relating to maintaining the microbiological control program shall be kept. Log sheets should be designed to keep the information listed below. Sufficient historical data should be readily available to the on-site operator.

The following data should be kept on a daily log sheet, preferably an electronic one:

- Biocide residual test results
- Biocide feed rates
- Biofilm monitor results
- Legionella testing
- Date, time and quantity added of biodispersants and non-oxidizing biocides
- Date and time of shock treatment
- Date and time of any shutdown or cleaning including the disinfection procedure

REFERENCES

1. ASHRAE 1998. American Society of Heating, Refrigeration, and Air Conditioning Engineers. Legionellosis: Position Paper. June 25.

2. Betz Dearborn Technical Bulletin 73, 2000. "Chemical Water Treatment Recommendations For Reduction of Risks Associated with Legionella in Open Recirculating Cooling Water Systems."

3. Betz Dearborn web-site, www.betzdearborn.com, "Information About Legionnaires' Disease that May Help Minimize Risk, A Discussion in Question and Answer Format."

4. Broadbent, Clive R. "Control of Legionnaires' Disease—An Australian Perspective." ASHRAE Transactions: Symposia, SE-99-3-3.

5. California Department of Health Services (DHS). "Minimizing The Risk of Legionnaires' Disease in Public Buildings." November 1995.

6. Cooling Tower Institute (CTI) 2000. Guidelines: “Best Practices for Control of Legionella.”

7. Davenport, Ken. “Real-Time Biological Monitoring.” Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

8. Environmental Protection Agency (EPA) November 1999. (EPA-822-R-99-001) “Legionella: Human Health Criteria Document.”

9. EPA March 2001. EPA-822-B-01-005 “Legionella Drinking Water Health Advisory.”

10. Geary, David F. “New Guidelines On Legionella,” ASHRAE Journal, September 2000.

11. Gregory, Jay S. “Who Should Be Responsible for Legionella,” Water Treatment Practical Guide, May 1999.

12. Hennon, Ken and Wheeler, David. “Cooling Tower Emissions Quantification Using the Cooling Technology Instutute Test Code ATC-140.” Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

13. Kang, Sukjun et al. “Multipurpose Water Treatment in Cooling Towers.” Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

14. Lane, John and Peck, David F. “Condenser Water Treatment Using Pulsed-Power.” Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

15. Meyer, Craig. “Controlling Legionella in Cooling Towers.” ASHRAE Technical Feature, IAQ Applications, Spring 2000.

16. Nalepa, Christopher et al. "The Control of Bacteria on Surfaces: Effectiveness of Bromine-Based Biocides towards Microbial Biofilms and Biofilm-Associated Legionella Pneumophila." Presented at the 2002 CTI Annual Conference.

17. Puckorius, Paul R. “Update on Legionnaires’ Disease and Cooling Systems: Case History Reviews—What Happened/What To Do and Current Guidelines.” ASHRAE Transactions: Symposia, SE-99-3-2.

18. Puckorius, Paul R. and Diehl, Ken. “Water Reuse Experiences With Cooling Tower Systems in San Antonio, Texas.” Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

19. Queensland Government, Workplace Health and Safety, February 2000. “Legionella Control in Airconditioning Units and Cooling Towers.” Supplement No 2 to the Plant Advisory Standard.

20. Smith, J.W. et al, Shell Global Solutions. "One Company's Legionella Standard." Presented at the 2003 Cooling Technology Institute (CTI) Annual Conference.

21. U.S. Department of Labor, Occupational Safety and Health Administration (US OSHA). "Legionnaires' Disease." OSHA Technical Manual Section III, Chapter 7.

22. Wiatr, Christopher L., Buckman Laboratories. "Detection and Eradication of a Non-Legionella Pathogen in a Cooling Water System." The Analyst, Spring 2002.